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Laser and Waterjet Cutting for Theatrical Costumes

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Laser and Waterjet Cutting for Theatrical Costumes

by

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Abstract

Laser and Waterjet Cutting for Theatrical Costumes

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As a costume technician, I am interested in ways we can incorporate new and different technologies into our craft. The use of laser cutting technology has become increasingly prevalent in the fashion industry to create one of a kind fabrics and embellishments on garments. I am interested in how we can use laser cutting to create costumes. For my thesis project, I will create three historically based costume pieces using a laser cutter and a waterjet cutting machine. The projects will be one: a jeweled metal crown inspired by the ducal crown of France, Italy, Spain, and Portugal as illustrated in Heralischer Atlas, by Hugo Gerhard Stroh; two, a 16th Century leather breastplate with laser cut and etched leather embellishments; and finally a re-creation on an early 20th century Edwardian lace collar and yoke.

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Chapter 1: Inspiration

The initial inspiration for this thesis came from an article published in the November 2010 issue of *Threads Magazine*. The article titled, "Cut to Order" was written by Kenneth D. King. King wanted to show that the use of laser cutter in garment making wasn't reserved solely for the major fashion design houses. In his article, he detailed his exchange with a laser cutting company in Ohio called Laser Cutting Shapes (King 55). King was able to send the company a scale drawing of the pattern and design he wanted to have cut along with the materials his garment was to be made of (King 55). The staff members of Laser Cutting Shapes were able to convert his drawing into a digital file, upload the file into their machines and cut his pieces and send them back to him for a fee (King 55). Until I had seen this article, the idea of using lasers to create clothing was completely foreign to me. With further exploration, I learned that Laser cutters have been used in the garment industry since the early 1970's presumably to cut garment pieces out of large stacks of cloth.

> "As early as 1974, CO2 lasers made an impact on the garment industry by their ability to cut cloth cleanly and quickly. Cutting speeds could be of the order of 100 m/min depending on the cloth weight. Edge fraying was eliminated, and for man made fabrics, a sealed edge was produced. At more moderate cutting speeds, several thicknesses of cloth could be cut at one time (Powell 115)"

Since then we have seen the use of laser cutting in fashion progress from basic utilization in the garment construction process to a technology used to create unique cut

out details on couture garments. Eventually the utilization of lasers filtered down to being used in creating interestingly detailed ready to wear garments sold at chain stores, or fabrics sold at major fabric retailers. More and more services are readily available like the one used by Mr. King that will convert a drawing provided by a designer into a vector file and will, in turn, laser cut your garment pieces or fabric yardages. The final product will be sent back to the designer ready for use. These services are now easily searchable on the internet.

With more and more of these laser cutting services becoming readily available I wanted to discern a way that I could use one of these services to create interestingly detailed costumes for theater. Thus, the plan was set into motion. I decided that for my thesis, I would create designs for theatrical costumes that would be embellished using laser cut leather and fabric details. I began by looking for laser cutting services in my area. I knew about the services available around the country, but I wanted to find out if I could work with someone locally. I wanted to observe the process up close and learn as much as I could about how the lasers worked, and what software was used to create the files. This proved to be a little more difficult than I had anticipated. One of the major laser cutting services in my area doesn't allow people to view their work room or see their machines. They were able to tell me what brand of machines they were using, but they had many nondisclosure contracts and only company personnel were allowed beyond the showroom.

With a little more digging, something new began to appear on my radar. There was a business in Austin that offered a laser cutting services for a small fee. This business

also made access to the laser cutters themselves readily available to the public. Twice a month, classes were offered there allowing anyone the opportunity to learn to operate a laser cutter. This place was called the MAKE ATX makerspace.

Chapter 2: Makerspaces

Makerspaces have become increasingly popular over the last few years. Many people have asked me over the course of this project, “What is a Makerspace?”

The simplest definition of a makerspace is given by Samantha Roslund and Emily Puckett Rodgers in their book *Makerspaces.* “The word makerspace is a general term for a place where people get together to make things. Makerspaces might focus on electronics, robotics, woodworking, sewing, laser cutting, computer programing, or some combination of these skills (9).”

The Make ATX makerspace primarily focuses on laser cutting. I took my first laser cutting class in February of 2015. The class was 3 hours long. During the class, we discussed how the laser cutters worked, the uses of the laser cutter, what materials were appropriate to cut, how to run the machine safely, and how to set up computer files so that they would be compatible with the machine. The teachers at the MAKE ATX space were quite informative. I was surprised to find out that several people who worked there that cut their own leather to make bags and other accessories. When we learned to operate the laser, we were able to make our own sample project. I made a small leather name tag.

When the class was over, I had a short discussion with the instructors about what it was that I wanted to do. I was uncertain as to what kind of software I would actually need to learn in order to make my own files for the laser cutter. They recommended that I learn adobe Illustrator. They also recommended that I build up several projects before I sign up for a membership to their makerspace. The monthly cost of membership would be expensive for someone not able to use the space on a regular basis

I didn't join the makerspace that day. I didn't actually end up working at the Make ATX space at all. I did, however, leave with a definite idea of where to begin. That was the hardest part. With more research I found out that there were two other makerspaces in my area, the Austin Hackerspace and the TechShop in Round Rock, Texas. After touring the additional makerspaces and taking the appropriate classes, I became certified to use the laser cutters at the TechShop and Hackerspace, as well as Make ATX. Ultimately I chose to work at the TechShop for reasons that will be mentioned later.

Chapter 3: Thesis Questions

After exploring the options of space, availability, accessibility and usefulness that were available to me I began to form the two main questions for my thesis:

How can laser cutting and waterjet cutting be utilized to create and enhance costumes, and how does the use of the laser cutter and waterjet cutter advance my work as a costume technician?

To begin answering the first question, I had to make a decision about what to make as my product. The decision wasn't easy. I wanted to make something interesting that would really feature the details one could get with a laser cutter and also make something that was theatrically practical and could be useful for others. Many ideas were tossed around throughout the planning processes of my thesis. I began with the idea of making a laser cut armor display. This was interesting, and I already had a good working knowledge of how to make leather armor. The problem was, how could I incorporate fabrics into this display? A second idea that came later in the planning process was a sort of high fashion hybrid. This second design would feature laser cut leather and fabric details, but started to get away from the idea of creating a practical theatrical costume. The Final idea for the products for this thesis was the creation of three small pieces that were historically based. I decided to make a leather armor breastplate, an Edwardian lace collar and a brass crown. I knew that the first two items would be fairly easy for the laser cutter to work through. The crown, however, required the addition of a new technology, abrasive waterjet cutting. I wanted to explore metal work, so that I would be able to feature 3 three items in three very different materials. Unfortunately the laser cutters at

the makerspaces weren't powerful enough to cut metals. Metal can be etched using the laser, but it has to be coated to keep the laser from reflecting back on itself and breaking the machine. That seemed to not be a problem initially. Some of the machines have rotary attachments so that you can etch into round 3D objects like glasses and wine bottles, unfortunately the attachments aren't large enough to rotate something as large as a crown over the laser bed. I then considered etching the metal while it was flat, but I was worried that I would ruin the coating while the crown was being shaped since I would have to pound it with a hammer around a head block. The third obstacle that presented itself was that I would have to cut the metal out myself by hand. This would be time consuming and having almost no experience in jewelry making meant that I wouldn't be able to make anything very detailed, at least not very well. In talking with my advisor, the waterjet seemed like a great alternative. Waterjet cutting is another form of computer controlled cutting and I could create the initial files in Adobe Illustrator. When I decided on a final product, I was able to begin the creation process.

Chapter 4: Preparation and Planning

Illustrator

I began the creation phase of my thesis, by learning Adobe Illustrator. All of the laser cutters at the maker spaces are compatible with most vector graphics software like CorelDraw, AutoCAD, and Illustrator. Illustrator seemed like the best choice for me because I had prior experience with Photoshop and other programs in the adobe suite. I began learning Illustrator by taking online classes through Lynda.com. Lynda.com is a website where people can pay a fee and take online classes in software and other skills. Access to Lynda.com has been provided to UT students free of charge. I spent eight weeks learning Illustrator through the online courses and working on practice files that were provided with the courses. Most important thing for me to get out of the lessons was learning to get comfortable with the pen tool. The pen tool is used for making line drawings in Illustrator. The laser cutters and waterjet read the line drawings sort of like a map in order to know where to place the cut lines.

When I finished with the online classes, I started practicing with the pen tool in Illustrator by creating basic clothing pattern drafts called slopers. Over time, I felt comfortable enough with Illustrator to begin creating the more detailed projects that I would need to create for my thesis.

Planning

During the period that I spent learning Illustrator, I also set out planning what I was going to cut out on my own and potentially have others cut for me. Something I

initially wanted to explore when I began working on this project, was what it was like to work with the already established laser cutting services. During this time, I was also planning to outsource the waterjet cutting as well. These plans slowly fell by the wayside for various reasons. When I started exploring the maker spaces, and learning how to operate the laser cutters, the more I wanted to make everything on my own. It didn't make sense to me to send out any of the laser cutting since I was already putting my time and money into learning the technique necessary.

When it came time to plan out how the crown was going to be cut, I took a picture of the research image on which I was basing product, to a local waterjet cutting service. The manager of the service studied the photo and told me that they couldn't help me. The Crown would be too detailed for the waterjet. I politely thanked them and left feeling deflated. I was going to have to figure out something else, then I remembered that the TechShop, the makerspace that I had mentioned choosing earlier, had a waterjet cutter, and a class on how to operate it. I decided that I was going to learn how to operate a waterjet myself, so that I could completely understand how it worked and also to find out for myself if my design was truly too complicated.

The TechShop

The TechShop is a makerspace that is part of a national chain of makerspaces. I joined the TechShop because the price of membership was similar to Make ATX and they offered a much broader range of experiences. I would have access to over one million dollars in tools and machinery including laser cutters and a waterjet cutter. The TechShop also offered multiple classes in a wide variety of subjects. In December of

2015, I took three classes at the TechShop that would prove to be very valuable during the creation process of my thesis.

I began by taking a 3 hour long class in how to operate one of their laser cutters. This class was very similar to the class I had taken at the Make ATX space. We covered setting up the machine, how to set up files and upload them into the machine, how to operate the machine safely, and how to clean the machine after we were done using it. During this class each student went through the full process with the instructor from start to finish in order to get hands-on experience from start to finish.

The next class I took at the TechShop was the CNC waterjet SBU. SBU stands for safety and basic use. You have to successfully pass this class in order to use the waterjet cutter at the TechShop. This class was scheduled to be 4 hours long. The first two hours were spent going over the software used to create files and operate the waterjet cutter. The waterjet works with two different programs in the same software suite. The First program is called FlowPath. Once your vector files are created, they must be uploaded into FlowPath in order to create a file compatible with the machinery itself. When your files are uploaded into FlowPath, you will choose the path the waterjet will take while it cuts your pieces and the speed at which the machine will cut it. The second piece of software is called FlowCut. FlowCut is the software that runs the machine itself. Each student in the class created the same file along with the instructor so that we would be able to get a handle on how to set up our projects.

The Second portion of the class was spent learning how to actually operate the waterjet machine. This process was quite daunting. The waterjet is one of the most

powerful tools in the TechShop. The instructor guided us through setting up the machine step by step. He provided us with a checklist of procedures to follow in order to make sure the machine was safe to use. We started by uploading our files into the machine and securing our materials to be cut into place. We were cutting out samples out of ¼" thick stainless steel. When everything was secured, we moved the waterjet into the proper position for cutting. The instructor cut a bottle opener from a sample file uploaded into the computer guiding the machine. Next, with the instructor's supervision each student set up the machine and cut out their own bottle opener. Once everyone had cut their sample, we were guided through shutting the machine down and cleaning the area where we were working. Once I successfully completed the class, I was certified to operate the waterjet.

The third class I took at the makerspace was a Jewelry and Metalsmithing basics class emphasizing sawing and riveting. During this class we learned how to cut thin pieces of metal using a jewelry saw. We also learned how to cut our own rivets out of thin pieces of brass tubing and brass rods. We used the rivets to connect the metal pieces we cut by placing them through pre-drilled holes in the metal and then pounding them into place. This class turned out to be just as valuable as learning how to operate the laser cutter or the waterjet. I knew I was going to cut a crown out of metal on the waterjet, and now I knew how to connect the ends to form the crown into a wearable shape.

Once I completed the safety and basics classes at the TechShop I spent some time creating small sample files of my own and practicing on the machines. The more I was able to practice, the more I felt comfortable with operating the machines on my own.

Chapter 5: Machines

Laser Process

Before continuing with the creation portion of this thesis it is best to discuss how both the laser cutter and waterjet machines actually work. The laser cutters at the TechShop, and the other makerspaces in Austin, are Co2 laser cutters. To start with, I would like to give a general overview of how laser works and more specifically how Co2 lasers are created. To understand the basics of how lasers work, it is best to begin with an understanding of how light works. Light creation begins at the atomic level. Light is created when an atoms reach an excited state or becomes unstable. The atom reaches this state when it is introduced to some form of energy causing the electron orbiting around the nucleus of the atom to jump into a higher orbit, making the atom unstable. Eventually the electron shifts back down to its original orbit around the nucleus in order to stabilize the atom. During this transition, the electron gives out the energy that is has absorbed as an emission of light called a photon (Woodford).

In his Article, Mathew Weschler states, “A laser is a device that controls the way that energized atoms release photons. ”Laser" is an acronym for light amplification by stimulated emission of radiation, which describes very succinctly how a laser works (4).” Every laser is set up in the same basic way. There is a laser cavity sandwiched between two mirrors. One of the mirrors is only a partial mirror. The medium in the laser cavity can be solid, liquid, or gas. The First laser invented was the Ruby Laser and was invented by Theodore Maiman in 1960(“The First”1). The Ruby laser is a solid state laser and seems to be the general model used to illustrate laser creation. No matter if it is a solid,

liquid, or gas, most lasers work in a very similar way. According to Weschler, “In a laser the lasing medium is “pumped” to get the atoms into an excited state (3). After the lasing medium is pumped, a handful of the atoms start to relax. During this relaxation the atoms release photons or particle of light, as mentioned in the previous paragraph. “The photon emitted has a very specific wavelength (color) that depends on the state of the electron's energy when the photon is released. Two identical atoms with electrons in identical states will release photons with identical wavelengths (Weschler 3).” In other words, all of photons released in the chamber are identical. The photons start to collide with atoms that are still in their excited state. The excited atoms cannot take on any more energy and are disrupted so much by this collision that it rejects the incoming photon, but also releases a photon of its own in the same wave length of the first photon. The photons travel in the same direction colliding with other excited atoms creating more and more copies of the same photons in the chamber (Weschler 4). A major component of making a laser are the aforementioned mirrors at the ends of the laser medium. The photons travel back and forth in the chamber between the mirrors stimulating more and more atoms, which have become re-excited, along their paths until the chamber starts to become full. The partially reflective mirror allows particles of light to escape. This light is laser light (Weschler 4).

In summary, atoms in a laser cavity are excited by an outside source (i.e. Light or electricity). When the atoms begin to relax, they release units of light called Photons. The photons bounce back and forth in the cavity continuously colliding with more and more atoms building up more and more photons. Light is released in small bursts through a partial mirror. This light is the laser.

CO2 laser cutters are primarily the cutters I will be working with on my thesis. In CO2 laser cutters, the laser cavity is generally filled with a gas mixture of CO2, Nitrogen, and helium (Powell 8). In a CO2 laser, the CO2 molecules go through the same lasing process mentioned in the previous paragraph. Helium and nitrogen are added to make the lasing process more efficient (Powell 8).

The waterjet

The second piece of machinery that is important to discuss is the abrasive waterjet cutter. The abrasive waterjet cutter works in a much different way than the laser cutter. The waterjet was invented in the early 70's initially without the abrasive component added to it (Powell 179). Initially, water alone was pumped through the machine as a highly pressurized stream. In the 1980's the abrasive component was added to the waterjet which is what allows it to cut through metals (Powell 179). John Powell Gives a good description of how the abrasive waterjet operates.

> "A hydraulic pump is used to pressurise water in an intensifier to pressures of the order of 50,000 psi. This pressurised water is then ejected from a small diameter nozzle. The high pressure water jet thus produced then passes through a chamber where it is mixed with abrasive powder before passing through a final nozzle to interact with the workpiece (powell 179-181)"

Basically highly pressurised water is forced through the machine and mixes with an abrasive powder just before exiting the machine into the material. The waterjet at the TechShop uses powdered garnet as the abrasive element. The abrasive powder in the water stream is now the main source of the cutting. This allows the waterjet to cut

through harder and thicker material. Like metals and granite. The waterjet is capable of cutting through brass sheet metal 1/32” thick to a slab of granite up to 8” thick. The Materials to be cut are place on a flat grate that sits just below the surface of a tank of water. The tank is large enough that it extends past the cutting radius of the machine both in width and length. The Water in the tank helps absorb and disperse the force of the jet. I would like to note that I was unable to get diagrams or images of the inner workings of the machines at the TechShop. The manufacturers consider it proprietary information.

There are similarities between both machines. They are both CNC controlled. CNC stands for computer numerical control. Essentially the machine looks at the drawing in the software, and converts it into a series of numbers. The numbers are like coordinates on a map that guide the machines along the path that they need to cut. The initial files for both machines can be created in any vector based software. There are also some pretty big differences between the two machines, aside from the fact that one uses water and the other uses a laser. Though CO2 lasers are often used to cut various metals, the lasers at the makerspace aren’t powerful enough to do so. The lasers at the TechShop are really only capable of cutting through materials up to ¼” thick. On the other side of that, the waterjet is more expensive to run. The laser is capable of continuously creating its own light, the waterjet relies on large amounts of water and garnet powder that cannot be repurposed once they have gone through the machine. Because of this waste, the makerspace charges a consumables fee for every minute that the machine is running. The waterjet also cuts at a considerably slower rate than the laser cutter. The laser cutter is much more capable of creating detailed cut. The kerf width, cut width, of a laser is

around 0.005” and the waterjet has a kerf width of the waterjet is 0.05”. At the TechShop, they do recommend that you test out any patterns that you created for the waterjet on the laser cutter if you can, in order to make sure that there are no flaws in it. Materials and time on the waterjet can be expensive, you don’t want to find out that you made a $200 mistake.

Chapter 6: Creation

As mentioned previously in this paper I decided to make three small historically based costumes, a metal work crown, a leather breastplate and a fabric collar. I've covered what I learned in order to make these products for my thesis. I've also provided a basic understanding of how each of the machines featured in this project operate in order perform their respective cutting functions. In this next section of my paper I would like to cover how each of my products were made using either the laser cutter or the waterjet as the featured tools utilized to create each piece.

The Crown.

The crown was the first of the pieces that I started creating, because I knew that it would take the most time to make. Quite often crowns for theatre are made of things like paper mache or felt and glue. I wanted to make mine out of metal. I wanted it to look as realistic as possible and I wanted to use the waterjet to see how long it would take and how finely detailed I could actually get. The initial inspiration for this piece came from an illustration of the ducal crown of France, Italy, Spain, and Portugal as illustrated in Heralischer Atlas, by Hugo Gerhard. The Leaf pattern for the crown band was inspired by the leaf pattern on a crown that is a piece from the crown jewels of the Royal Family of Denmark, photographed by Leroy Andersen. The final piece was made to match the leather breastplate.

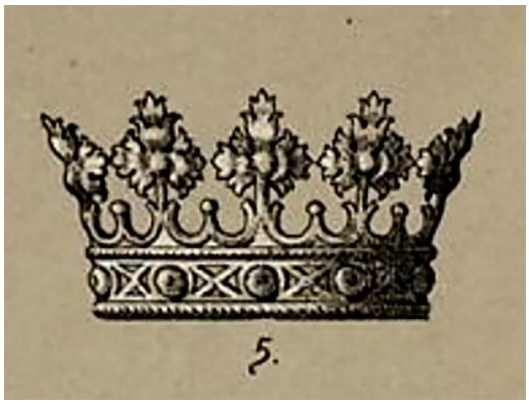

Figure 1: Fig. 5, Hugo Gerard Ströhl, Heraldischer Atlas, (Julius Hoffmann 1899 panel 16)

Figure 2: Andersen Leroy. "The Queens Crown." 02 September 2013. Online Image. Flickr. 12 February 2016.

I started creating the design of the crown by enlarging a photo of a research image until it seemed to look like a good life size scale. I checked the scale by holding the image up next to my head in the mirror. When I was happy with the size of the image, I placed it under a piece of tracing paper and traced around the details that I wanted to use

to create the elements of the crown. When I was finished with the tracing, I laid the transparent paper onto a white background and photographed it with my smartphone. I then uploaded the photo into Adobe Illustrator and began tracing around the drawing with the pen tool. In order to make sure that the piece would be symmetrical I only traced half of the drawing. Then, using the transformation tool, I copied and reversed the drawing and merged the two lines together to make one whole object. After the first object was created, I started duplicating it until I had multiples of the same drawing. I merged all of the copies together to create a repeatable pattern that I could group into a line drawing the length and scale appropriate for the crown. The pattern was made to be 23 inches long in order to create a mock-up crown band the measurement of the model's head plus seam allowance.

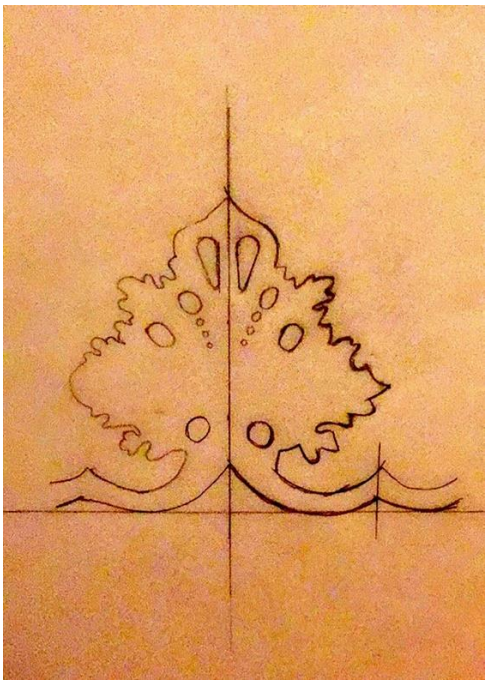

Figure 3: Leaf tracing

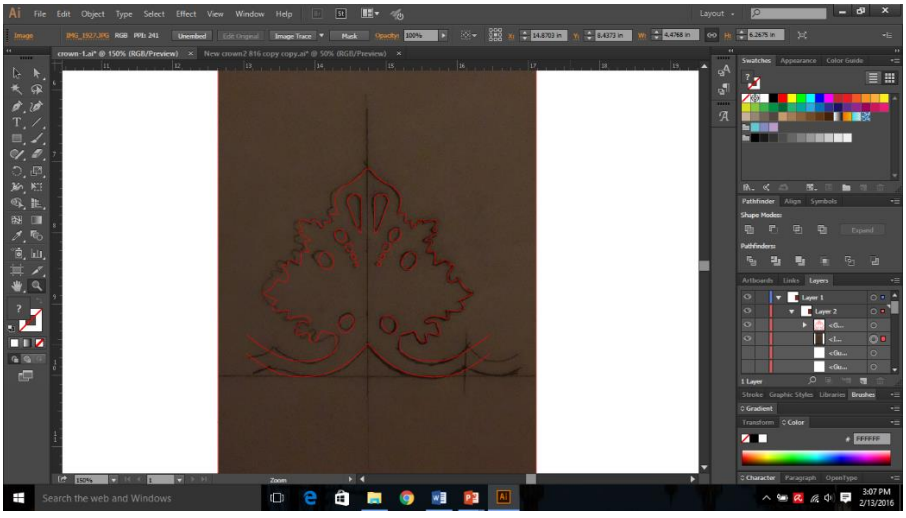

Figure 4: Illustrator leaf tracing

After the file was created to the size I needed, I had the image printed on a sheet of paper measuring 24x18”using a large format printer at Staples office supply store. The dimension of the laser bed I would be working on is 24x18. After the Initial mock up

fitting, I planned to make a prototype on the laser cutter at the TechShop. I pasted this print out onto mat board, cut it out and joined the ends together in order to create the mock up for fitting. All of the pieces were created for a specific actress. It was important to me that all of these pieces were actually wearable as if they could go on stage, also I wanted the experience of fitting all of these pieces

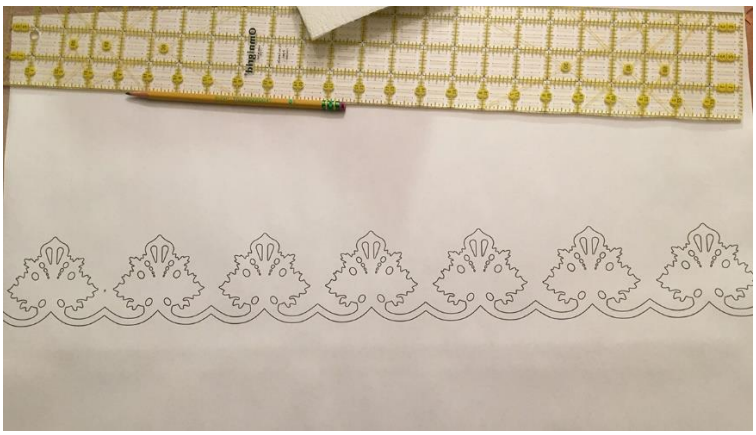

Figure 5: Printed crown pattern

Figure 6: Crown mockup

During the fitting we discovered that the crown was too big for the actress' head measurement, adjustments would have to be made. Essentially the adjustments were made by slightly reducing the size of the line drawing proportionally to the new measurement in Illustrator. The updated file was uploaded into the laser cutter at the TechShop and then cut from 2 ply chipboard again. I used chipboard for all of the crown mock-ups because it was easy to shape and adjust but also stiff. Once again we fit the new mock up to the model to check for adjustments. The second mock up fitting was quite successful and so from there I began to pattern the prototype.

Using the mock up as a base I began designing other elements that I could use to give the piece dimensionality and also potentially cut with the waterjet or laser cutter.

Figure 7: Crown prototype

The prototype for the crown was once again made of 2 ply chipboard and cut on a laser cutter. The prototype is actually cut in 3 pieces. The back piece is the leaf pattern

shown in the previous photos. The middle layer is an etched band that will be made of leather and the outer layer is a series of smaller leaves that will hold resin gems. All of the layers are held together with paper brads.

When the prototype for the crown was approved, I was able to begin the actual creation process. I chose to make the crown out of 20 gauge brass sheet metal. I purchased a 3x3' square of brass at a local sheet metal supplier. This was to ensure that I would have enough material to cut all of the pieces I needed to assemble the crown. There are 28 metal cut pieces on the crown total.

The Illustrator files that I used to create the prototype were converted into files compatible with the waterjet using Vcarve Pro, FlowPath, and FlowCut software. The software was provided on computers for use by members at the makerspace.

FlowPath is the name of the software used to create the file to be used by the waterjet. One can import line drawings from most vector graphic softwares to Flowpath in order to prepare the cut files for the waterjet. Since I created my files in Illustrator, it was explained to me at the makerspace that I would have to import my files into Vcarve Pro, and then export them into FlowPath in order to maintain the correct shapes of the line drawings. Vcarve Pro is a software designed to create files for CNC routing.

In FlowPath you can chose the path and speed of the waterjet as you are cutting the material on the machine. Pictured here is one of the smaller crown pieces uploaded and pathed out in FlowPath. The red arrows indicate the path that the waterjet will take when cutting out the metal.

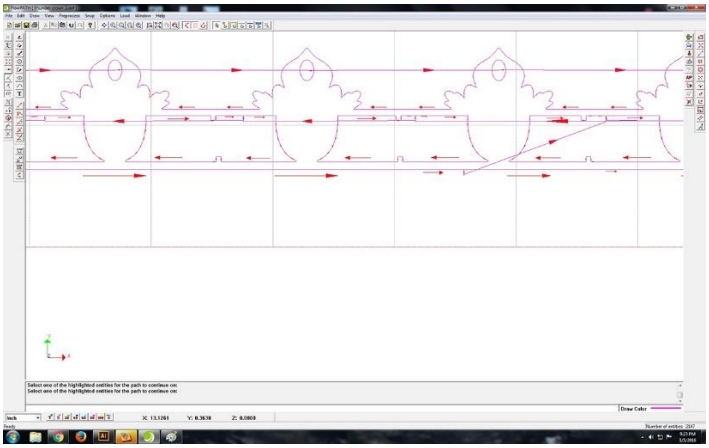

Figure 8: Crown pattern in FlowPath

After the files are prepared in FlowPath, they must be exported as a file compatible with the cutting software that is used to control the waterjet itself. The software is called FlowCut. FlowCut communicates with the machine, by providing the path for the machine to take based on the line drawing in the file. The speed of the machine that was set up in Flowpath is also calibrated in FlowCut by setting the type and thickness of the material you are cutting. Pictured here are the crown files uploaded into FlowCut on the waterjet machine.

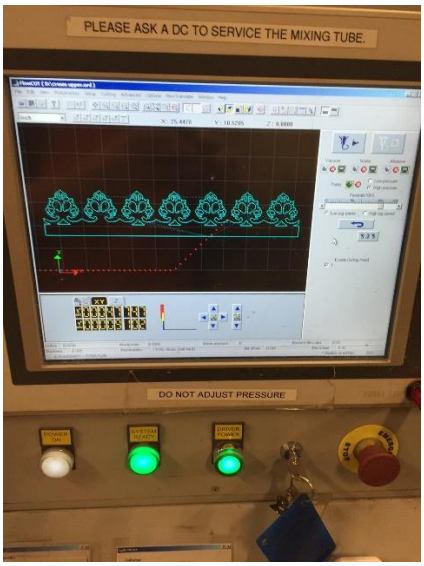

Figure 9: Crown pattern in FlowCut

Below is a full view of the waterjet machine. The material to be cut must be weighted down on a grate over the tank of water so it won't shift around and interfere with the cutting process.

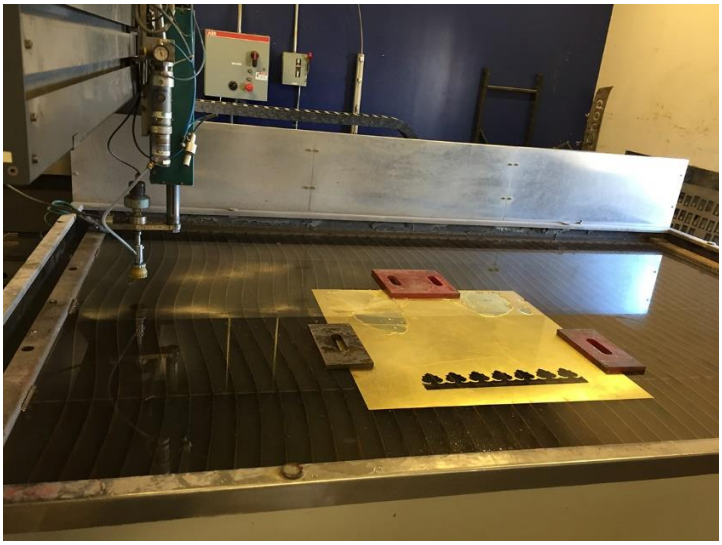

Figure 10: Full view of waterjet cutter

The water travels through the machine and mixes with the garnet in the mixing tube just above the yellow nozzle on the machine. The water in the tank absorbs the pressurized water and garnet mixture coming from the machine.

Figure 11: Waterjet cutting through brass

Figure 12: Finished crown piece

It took approximately 2 hours for the waterjet to cut all of the pieces for the crown. There were 22 cut in total, one large crown band, 7 smaller decorative pieces, 7 larger gem holders, and 7 smaller gem holders. Once all of the crown pieces were cut I cleaned them with a polishing cloth and began assembling it. I began shaping the main crown band by pounding it around a head block with a brass hammer. I worked the band around the head black until the seams touched without forcing them together. I had planned to close the seam using brass jeweler's solder. When soldering a circle together the metal piece must be fully shaped all the way around until the seams touch. If the piece isn't shaped properly, there may be too much stress on the seam for it to hold. Unfortunately, I was unable to achieve a proper solder due to lack of experience with the process. To hold the ends together I backed the seam with a small piece of brass and held it in place with hand pounded rivets cut from small pieces of brass rod.

Figure 13: Shaped and closed crown pieces

The final crown was assembled by gluing an etched leather strip around the crown band, and hand pounding rivets through gem holding prongs, and front pieces using a brass tube. I finished the crown by texturizing and shaping the leaves with a ball peen hammer against a miniature anvil. I also decorated the crown with resin gems that were place by bending the prongs of the gem holders around them.

Figure 14: Crown during assembly

Figure 15: Finished crown

The Armor

The second part of the project is a leather breast plate featuring laser cut and etched trim details. The breastplate was inspired this armor worn by Holy Roman Emperor Maximilian II of Austria.

Figure 16: Harrsch, Mary. "Armor of Holy Roman Emperor Maximilian II of Austria 1550-1560 CE etched partially blackened and gilded steel (2)." 07 April 2011, online image, Flickr, 12 February 2016.

The file creation for the armor details began the same way as the crown, I was able to find a detailed image of the etching of the armor and traced it onto a piece of tracing paper.

Figure 17: Hand trace of armor detail

I photographed the drawing with my smartphone, and then uploaded the image into Photoshop to clean the drawing up little. The drawing was rather dirty in some places and had some graphite smudging along the drawing. In image was cleaned by placing a levels mask on the image and then erasing the negative areas around the drawing. When the drawing was cleaned up it was exported into Illustrator and traced it with the pen tool the same way that the crown design was traced. I traced the drawing in 3 sections.

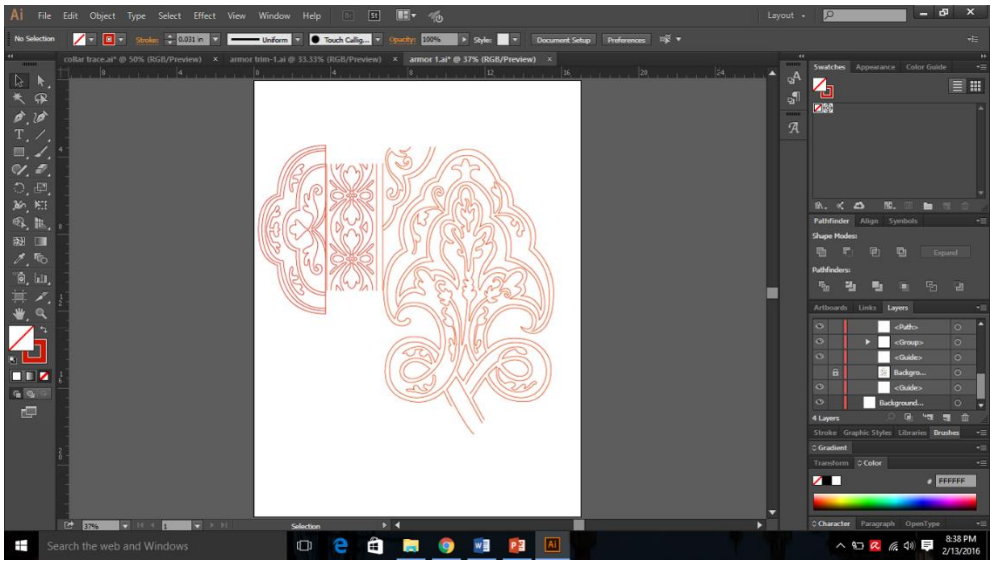

Figure 18: Armor detail traced in Illustrator

I used the initial trace to create a repeatable pattern by arranging and grouping the different sections, duplicating them, and then merging them. After the pattern was created, I grouped all of the paths together and set the image to be about 5 inches wide and 24 inches long.

Next, I printed the image on a large format printer to get an Idea of actual scale to see if I needed to make adjustments based on the size of the finished breastplate. The print out pictured is 24x18” to make sure that the piece will fit on the laser bed.

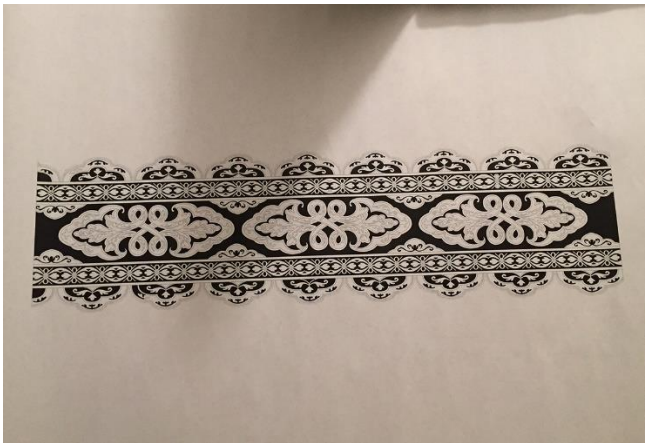

Figure 19: Armor pattern print out

After the adjustments to the file were made, I used the live paint tool in Illustrator to fill the images with the appropriate colors, black, blue and red, for etching and cutting. This image shows the final armor file set up with the red cuts and the black and blue fills for etching and printing.

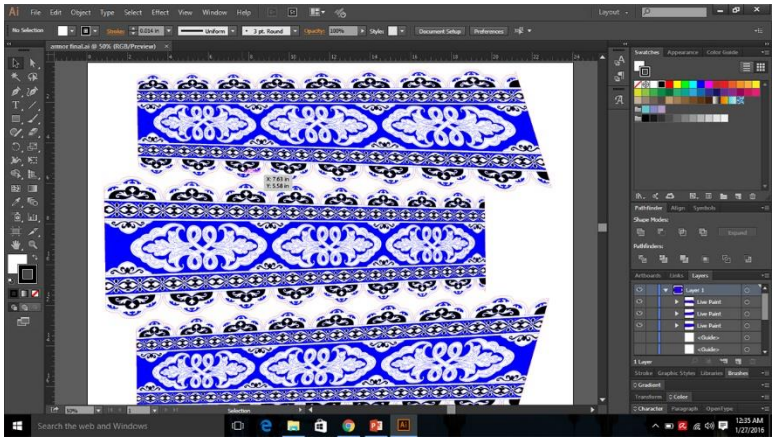

Figure 20: Filled armor pattern in Illustrator

The laser cutters at the makerspace are set up to recognize each of these colors for a specific purpose. Illustrator files are generally set up in RGB. This means that red, blue, and green are the primary colors used to make the color images you seen on your

computer. If you wanted to, you could set the laser cutter to use green as the color for cut lines as long as the machine is set up to recognize it as the color for cutting. When setting up files for laser cutting in Illustrator cut lines must be set to Red 255 with Green and Blue set to 0 in order for the machine to understand where to cut. Any etched patterns must be set in blue or black. The Blue for etching must be set to Blue 255 with Red and Green set to 0.

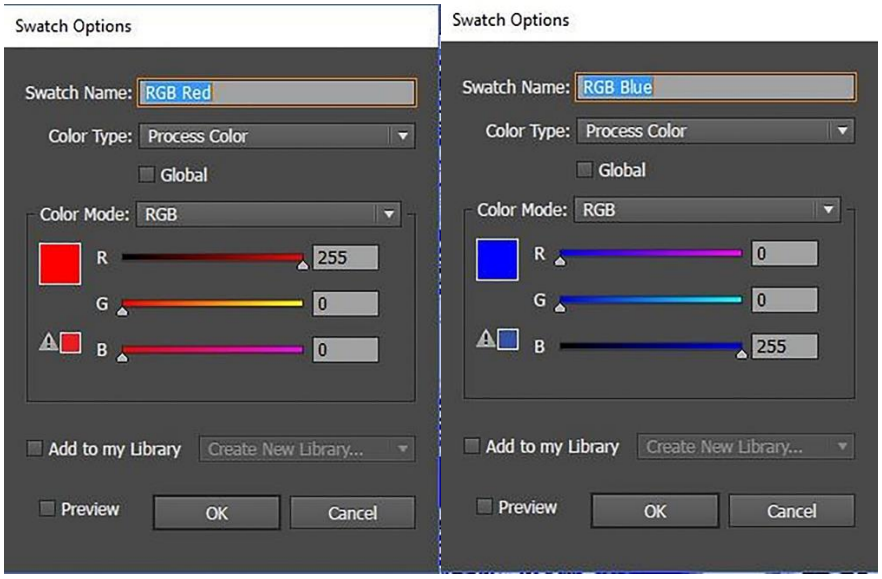

Figure 21: Color setup in Illustrator

Additionally, all cut lines made in Illustrator should be set to .001 or .003 pt. It is important to note, if the cut lines or fills are not set to the correct color or size, the laser cutter will not read them and you will not get the results you were expecting For example, I set up a file for the armor in the laser cutter not realizing that my line width for cut lines was incorrect. I printed my designs on a 24/18” piece of leather and nothing was cut out leaving me with a piece that I couldn’t use.

Many laser cutters on the market today are marketed to be as easy to operate as a printer. The laser at the makerspace is connected to a computer similarly to a printer. Once the files are created appropriately in Illustrator, one can click the print button, open the preferences and connect to the print setup of the laser cutter. From there one can select the type of material to cut, the thickness of the material and power level of the machine to cut through. Once your preferences are set, you can click print in the laser cutter setup and then print in Illustrator. When everything is set to print, you can open the laser cutter software that will show you your image as it will be placed on the bed. You can shift the image to where you want it to be in the cut area and then click print. The laser cutter will then begin the cutting process. The materials on the laser bed must be as flat as possible and appropriately weighted down. This will ensure that your etch patterns or cut lines are not distorted.

Figure 22: Laser cutter etching leather

During the file creation process for the armor, I molded the leather breastplate that would be decorated by the laser cut pieces. The leather used to create the breast plate was soaked in a tub of warm water for about an hour, until the water started to look almost

like tea. The soaking made the leather pliable enough to then stretch over a body form to create the desired shape. Once the leather was shaped, I tied it in place with strips of muslin and left it to dry for about 24 hours.

Figure 23: Leather armor molded on form and dried

Once all of the pieces for the armor were cut and shaped, it was ready to paint and assemble. Cutting the pieces on the laser took approximately one and a half hours. I began assembling the armor by staining all of the laser cut pieces with Eco-flo leather stain and then painting into the finer etched lines to highlight the detail. I painted the edges with the same stain mixed with gold luster powder to help the design pop. The breast plate itself was painted with Eco-flo silver acrylic paint and then given a light coating of Eco-flo black gel antique to help it look more like aged metal. After everything was painted the trim pieces were placed and fixed onto the breastplate with Barge

adhesive. The final piece was then sealed to protect the finish. In the future, a matching back plate will be created for a more complete look that can be used as an actual costume.

Figure 24: Leather trim pieces painted and stained and finished breastplate

The Collar

The last piece created for my thesis is a laser cut lace collar inspired by a handmade collar made 1900-1909. This collar is from my personal collection.

Figure 25: Handmade lace collar

I started this project by laying the actual collar out on a scanner in order to get a detailed image. The collar had to be scanned in sections in order to get flattened images of all the pieces. Next, I uploaded the images into Illustrator like the other pieces in this project.

Figure 26: Scan of collar

Once, the images were uploaded into Illustrator I traced them out with the pen tool. The collar was traced in three separate pieces in order to make sure that the pieces would fit in the laser bed. The collar presented a challenge in that there were many fine details that I would not be able to accurately recreate. In the finer sections I tried to create patterns using a series of diamond, triangle, and oval shapes. I also had to carefully factor in seam allowance for future assembly.

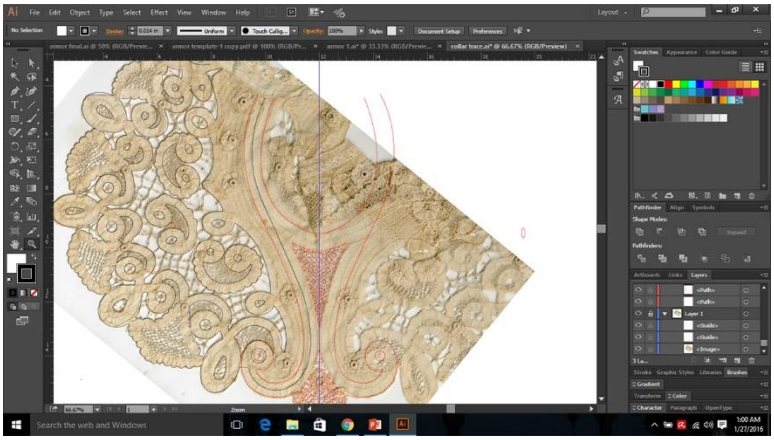

Figure 27: Tracing the collar in Illustrator

Cut lines for the pieces were set to .003pt and the appropriate red color for the machine to read. Note: all of the cut lines in the photos have been enlarged to .16pt to make them more visible.

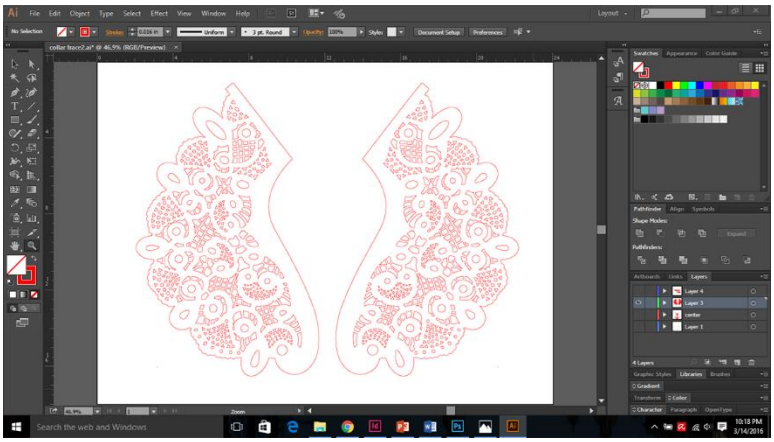

Figure 28: Full collar trace in Illustrator

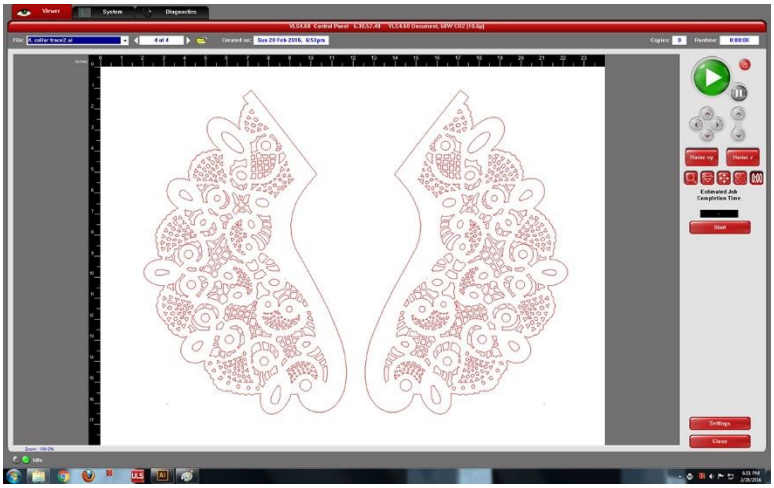

Figure 29: Collar uploaded into the ULS software

Initially, I chose to make a mockup of the collar using bleached cotton muslin. At the TechShop, most fabrics can be cut on the laser cutter, but it is preferred to cut projects from natural materials, or other products that won't be excessively flammable or release toxic gasses. Products made with PVC plastic, or vinyl, generally things like faux leather, are prohibited as they release hydrogen chloride gas which is both harmful to the machine and the operator. If you are unsure about cutting something with the laser, most makerspaces or laser manufactures will have a list of approved and unapproved laser material. If you are unsure what a product is made of, it is recommended that you find the MSDS, material safety data sheet, and make sure that is isn't made of any unapproved materials.

Initially I was concerned about cutting fabric on the laser. I knew it was possible, but there was a challenge in finding a way to keep the fabric in place during the cutting process. The laser cutter has an air assist next to the laser that blows a jet of air at the contact point of the laser. This can cause your fabric to blow around on the laser bed.

There is also an exhaust suction vent next to the laser bed to remove smoke and char. To account for this you must make sure that the fabric or any material are properly weighted down. When initially testing a swatch of fabric, I forgot to weigh it down. I closed the lid of the cutting bed, turned on the exhaust, and just as I was about to turn on the laser, my swatch was sucked into the exhaust. I later discovered that a special vent cover had been engineered at the TechShop to prevent that very situation.

Having learned from my previous mistake, I prepared the collar fabric for cutting by mounting it to a piece of 2 ply chipboard with Sulky KK2000 spray adhesive so that the fabric wouldn't shift inside the machine and interfere with the cutting process. I chose this adhesive because it is eco-friendly and powders off the fabric after a few days or you can accelerate the process by ironing it with a hot dry iron. Pictured below is an image of the laser cutter cutting through the fabric and the board.

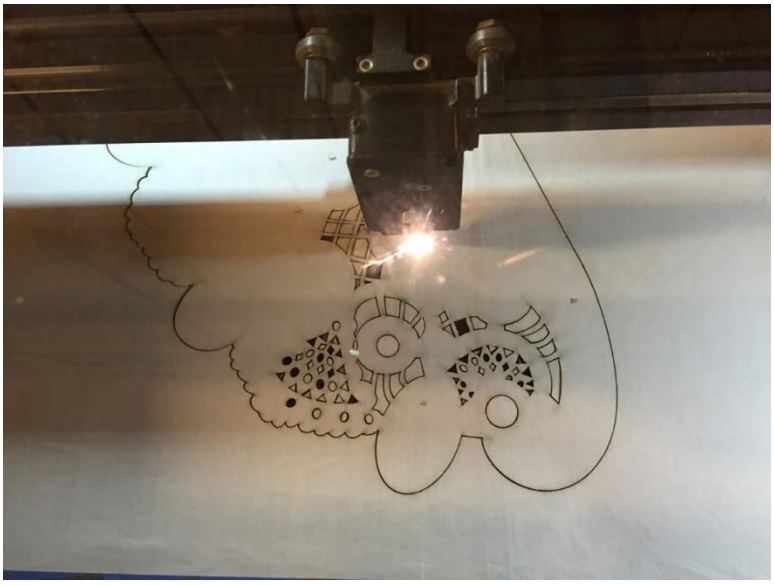

Figure 30: Collar being cut by the laser

Figure 31: Finished collar cutouts

The collar was cut in 4 sections to ensure that all of the pieces would fit on the laser bed. It took approximately an hour for the laser to cut the collar. When all of the pieces were cut, I laid them out on top of each other to make sure they would fit together. The collar band is not pictured.

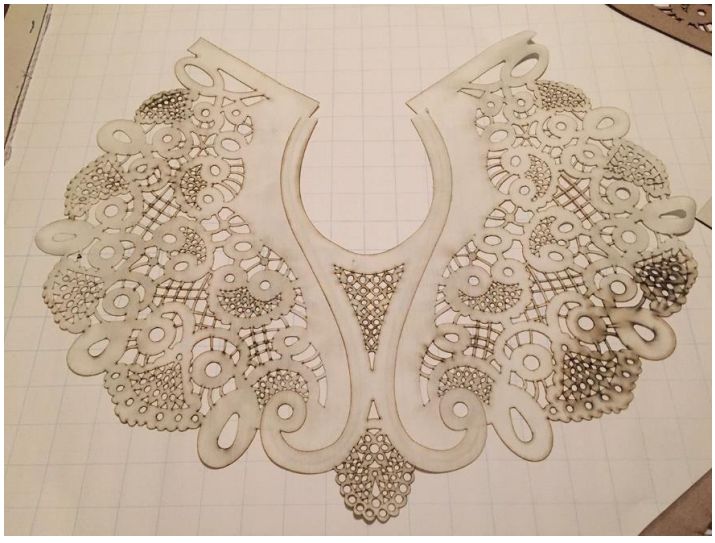

Figure 32: Collar pieces laid out

To help stabilize all of the pieces, I stitched them individually to bridal netting, freeform quilting around the scroll work and the delicate areas. I used a Bernina 1080 home sewing machine. I set the machine up for freeform sewing by dropping the feed dogs and attaching a hooped foot to that machine that doesn't put pressure on the fabric.

Figure 33: Collar piece flat lined to bridal net

After all of the collar pieces were backed with the net, I soaked them in a tea bath to give them a slightly aged look. Soaking them also helps remove some of the char that stained the pieces along the cutting lines. When all of the pieces reached the color I wanted, I lightly rinsed and dried them. Lastly I coated the underside of each piece with Aleene's Stop-Fraying to add extra durability to the pieces

Figure 34: Collar pieces in dye bath

After all of the pieces were stabilized, I trimmed away the excess bridal net. I then top stitched the collar pieces together to highlight the cut edges.

Figure 35: Topstitching on collar

The image below is a finished mockup of the actual collar that was fit to model.

Figure 36: Finished Collar mockup

After fitting the collar, alterations were made to the pattern in the computer. The angle of the center back had to be shifted and an extra section had to be created using elements of the existing file in order to extend the piece out along the bottom edge. When the files were edited I recreated the process used to make the first collar. I chose to make the second collar out of a 60/40 cotton poly blend. The cotton collar began to fray and the more delicate areas became extremely brittle. Synthetic fibers melt and help seal the cut edges when they are burnt with the laser. This creates a more stable product which is more desirable for theatrical applications.

Chapter 7: USITT Poster Session

For the performative element of my thesis, my advisor and I decided that I should try to present my work in the Costume Design & Technology poster session at the national 2016 United States Institute of Theatre Technology (USITT) Conference in Salt Lake City. If I were to be accepted, it would provide a good hard deadline for me to create my work. To apply to the poster session I submitted an abstract of my project to a panel of adjudicators. Applicants were asked not to provide any personal information in order to maintain anonymity. Once all of the abstracts were juried presenters would be chosen.

I was notified on December 2, 2015 that I was chosen to participate in the 2016 poster session. Along with the notification of my acceptance, I was given guidelines for what I would actually have to create for the poster. I was to create a detailed digital archive document and then a physical poster 4' x 4' in size both detailing the creation process of my products in a way that would help others understand how my pieces were made, and also give them an idea of how they might attempt a similar project for themselves. The digital poster was submitted two weeks before the conference. The physical poster was presented on March 17, 2016 during the costume poster session. Each participant was given half an hour to set up their displays before the public was allowed to view them.

The poster session was a great experience. I was able to talk with costume professionals from all over the country. It was interesting to observe the responses to the project. I was surprised by the number of people who were unfamiliar with the idea of

makerspaces. I was also surprised by the number of professionals who hadn't considered the use of laser cutters in processes of costume creation. I got some really great comments from people who would like to see me take the project further. The Idea of using a more textured fabric for the collar to give it more dimension was mentioned several times. Not all of the feedback was positive. Some had their doubts as to whether the fabric lace would look realistic enough from the stage. Some thought that maybe the design on the armor might be too intricate for stage.

Overall the poster session provided me with a great collection of ideas and thoughts on how to enhance my work and take it further.

As mentioned earlier, I was able to answer my first question by working through the creation process. In making the armor, I was able to use the technology and explore exactly how much detail I could apply to a costume piece. When I was making the collar, I recreated a piece of historical lace that is less precious than the actual piece and is more practical to use on stage.

Chapter 8: Where do I go from here?

The Second question I wanted to address was: How does this advance my work as a costume technician? I was able to advance my work as a costume technician by reaching beyond traditional methods of costume creation and combining them with new technologies that I hadn't previously thought to use to make costumes. Working on this project has pushed me to develop some new skills in costume crafts, (light metalworking and jewelry making). This project also required me to learn several software programs that I never thought would be relevant to costume making, but now I think that there are many new and interesting ways to integrate them into my process.

Prior to working on the crown, I had an extremely limited knowledge of jewelry making and metal work. Taking the jewelry cutting and riveting class at the TechShop, helped me get an idea of the sort of work it would take to cut the crown pieces by hand. Learning to cut metal with the jewelry saw also gave me an appreciation for what I was able to accomplish with the waterjet. I gained the experience of shaping the metal work. Though the soldering on this project was unsuccessful, I now have an understanding of the process and I feel that I could attempt to solder with more success in the future.

I feel that I can use what I have learned about laser cutting to help create a system of stream lining decorative costume elements. Hand working leather is beautiful, but can be difficult and time consuming. Laser cut detailing in leather can be much more precise than etching it by hand. Also once I have created the appropriate file, I can replicate the same piece over and over again. For example, if I needed 8 more breastplates with the same detail work that I created for the initial one in this project, I would be able to make

8 more sets in a matter of hours. The Pieces would come out of the laser cutter ready to paint and apply to their breastplates. The initial file for the armor took about 40 hours to create. I believe it would have taken almost the same amount to time to create one piece armor, but once it is finished, the replication process is much faster.

Creating the lace collar was a great way to explore, first hand, the use of the laser cutter on fabric. I also think it was a great way to explore re-creating a historical piece of lace for the stage. Antique lace is often used to enhance period costumes. It is my personal belief that one should avoid using actual period artifacts on stage. Lace especially is very delicate and often not suitable for the wear and tear of theatre. Copying and remaking pieces like the collar on the laser cutter could create a great alternative. With more exploration, I believe I could develop a more realistic product that would be sturdier than the actual artifact and also easily replaceable.

I believe I will also be able to advance my own work by sharing what I've learned with others. What most people want to know is that they can also use this technology and that's not something to be intimidated by or afraid of. I was terrified of learning how to use Illustrator, let alone a laser cutter or waterjet, but I was able to explore the resources around me. I want people to know that this technology is becoming much more readily available to the public. There may be a laser cutter or makerspace in their area that they might not have been aware of before. Alternatively, as previously mentioned, there are more and more services that will cut fabrics and other materials for you. I believe more and more people should be able to utilize those options if a local service is unavailable.

Other important things people should consider before applying this technology are time and money. Most shows in a regional theatre costume shop have a 5 week build period. File creation can take a good deal of time. The Files for this thesis took approximately 80 hours combined. Choices of what is going to be made should happen very early on in the build process. This also allows for research and development of the product. Not everything will come out perfectly the first time.

Cost is another thing to consider. Most theatres want to keep show costs to a minimum. Waterjet cutting, in particular, can be quite costly. The crown project cost about $250 for the cutting alone. The TechShop charges a consumables fee of $2.00 per minute and the waterjet has a much slower operating time than the laser. Waterjet cutters in the area gave me quotes comparable to what I paid to cut it myself. Makerspace memberships and classes can also be costly. The makerspaces in Austin offer a student rate which assists making access to their machines more economical. I do believe, however that students should explore options that may be available on campus before looking at a cutting service or working at a space out in the community. University costume shops, may also want to find a way to propose some sort of collaboration with other departments that hold their own makerspaces in order to reduce costs. Most makerspaces I have encountered also allow members to cancel their monthly membership at any time. Some will even allow people who have been certified to use the machines to purchase a day pass if they don't have enough work to warrant the cost of a monthly membership.

Chapter 9: Reflection

One of the most challenging things about this project, honestly, was not being afraid of the technology. I've never considered myself a very tech savvy person. Things got off to a rather slow start when I began learning Illustrator. Most of this past summer was spent learning and practicing the program along with a video course on Lynda.com. There was a great deal of trial and error until I began to actually feel comfortable creating my own files.

Similarly to learning illustrator, working with the machines felt quite daunting. Both machines are quite powerful and can be very easily damaged if you're not careful. The waterjet was especially intimidating. It is one of the most powerful machines at the TechShop. The cutting tip, however, is quite fragile and you have to be prepared for the garnet to clog in the mixing tube at any moment. Even with the procedural checklist, it took several uses before I felt truly confident using the machine. The laser also took several uses with an assistant before I felt comfortable enough to set it up and use it on my own. I also had to develop my own way of cutting the fabric in the machine. I had spoken to a woman who cuts quilt pieces on the laser and asked her what she does to keep per fabric stationary. She told me there was nothing i could do and that I would have to just start over if the fabric was ruined. That seemed foolish to me. When I first decided to mount the fabric. I sandwiched it between two pieces of chipboard. The pieces started separating during the cutting process and the material was flaming between the two layers which caused one of my test pieces to come out charred and almost unusable. It took another try before I got the mounting process fully solved.

Preparing for the poster session was also quite challenging for me. It wasn't making the poster or the digital archive so much as having to meet so many people. Putting myself forward is difficult at times and I was honestly really nervous about how my thesis would be received. I was really surprised that everything went so well. People were interested in my work and the technology and, I hope, it inspired other people to explore their own projects with the laser cutter and maybe the waterjet. I got a lot of great feedback from presenting my work. In moving this project forward, I would really like to find more interesting ways of getting texture into the laser cut fabric pieces, I would also like to try expanding, my projects to full garment pieces if it's possible. I want to do more work with leather, and maybe find a way to do some mixed media pieces. I think, overall, this project for me was about pushing myself out of my comfort zone just as much as it was about learning a new technology and creating costumes and that experience has advanced my work and, and my confidence, as a costume technician and an artist.

Appendix A: Supplies Used

Plastic body form
Dress form
Plastelina clay for padding plastic body form
3 half shoulders 5-7 ounce leather: purchased at Tandy Leather
Eco-flo Silver acrylic paint: purchased at Tandy Leather
Eco-flo briar brown leather stain: purchased at Tandy Leather
Eco-flo black gel antique: purchased at Tandy Leather
Barge adhesive
20 gauge brass sheet metal: purchased at Westbrook Metals Austin
3/16" brass rod
1/4" brass tube
Ball peen hammer
Brass mallet
Miniature anvil
Butane blow torch
Flux
Silver plumbers solder
Battery power drill w/ titanium drill bits
Jewelry saw and saw blades
2 ply chipboard
2 yds cotton muslin
2 yds polyester cotton broadcloth
2 yds bridal netting
Silky kk2000 spray adhesive: purchased on Amazon.com
Aleene's Stop-Fraying: purchased at Jo-Ann Fabric and Crafts

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